winds from the interior and the winds from the ocean. Supposing the wind to blow continuously in either one of these directions we should certainly have no rain. The dry north wind cannot deposit the wet which it does not contain. The sea breeze, coming from the south, has its tendency to absorb moisture increased as it proceeds northward, and will consequently give no rain.

If, therefore, we suppose that from whatever cause, at any time, there may be a more than usually steady current and uniform pressure in the ocean winds, off the Australian coast, we find at once, an adequate proximate cause for a drought on the land. As to the ultimate or remote cause, we have at present no data even for probable surmise, unless indeed we ascend another link in the chain of causes, and attribute the circumstance to the accidental absence of storms in the adjacent regions. On this subject at least a point is gained when a fallacy is cleared away. It is to be hoped that the result of simultaneous observations, which, under the patronage of the Board of Trade, are now about to be made at sea, in all parts of the world, will in due time throw a light upon this subject: I now conclude by recommending a co-operation in this important investigation, as one of the most legitimate objects to which the attention of the Philosophical Society could be directed.

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ART. XIV.—*On the Probable Influence of Evaporation on the Quantity of Water to be supplied by the Reservoir at Yan Yean. By* CLEMENT HODGKINSON, C. E., *Survey Department.*

AT the last Meeting of the Philosophical Society, after Dr. Wilkie's Paper on the anticipated failure of the Plenty Scheme of Water Supply had been read, and your Committee's Report received, the President, in the course of a few terse and apposite observations, directed the attention of the members of the Society to the necessity of further elucidation of the phenomena connected with evaporation.

I quite concur in the President's opinion that the excessive difference in the estimated effects of evaporation on the surface of the Upper Plenty District by Dr. Wilkie and your Committee, calls for further investigation.

For Dr. Wilkie, on the authority of Thompson's computa-

tions for the basin of the Clyde, assumed that in the Upper Plenty District the evaporation would leave only one-ninth of the total rainfall available for the Yan Yean reservoir; whilst your Committee, Messrs. Acheson and Christie, adopted, on the authority of Tables VI., in Dempsey's treatise on Drainage (which Tables they considered corroborated by their own observations), 0·42 as the amount of the total rainfall available,—a quantity nearly four times greater than that assumed by Dr. Wilkie.

Before discussing the very numerous measurements and experiments made in various localities and climates, and which, in the existing want of a regular and connected series of guagings of the Plenty, afford data for arriving analogically at an approximate determination of the proportionate amount of rainfall in the Upper Plenty District, I wish first to remark that in a tract of country of specified area comprised by a watershed, the proportion between the total amount of the annual rain falling thereon, and that portion of the rainfall that is carried away from it by the main channel of drainage, depends not only upon the climate, geological structure, and vegetation of such a tract, but also (although in a much less degree of course) upon the greater or less extent of the area; as, *cæteris paribus*, the greater the area the longer would be the aggregate distance that the rain water would have to traverse in order to reach the point of outfall of the tract, and consequently the longer time would such rain water be liable to evaporation before final departure from the tract in question at the lowest level. Hence, if a large tract and a small tract present the same physical configuration as regards surface, with the same climate and rainfall, the rate of evaporation for the large tract would be slightly in excess of that for the small tract.

The most extensive and minutely accurate observations ever made in Great Britain for the determination of the evaporation from surfaces of land and water under various conditions, were those taken at Ferrybridge, in Yorkshire, by Mr. Charnock, Vice President of the Meteorological Society of London. These observations were extended over the five years terminating 1846; and tended to corroborate the general accuracy of Dalton's observations at Manchester for the years 1795, 96, 97. Howard's Table, referred to in recent computations by Mr. Ranger, the well known Engineering Inspector under the Board of Health, gave for England generally a rate of evaporation rather greater than that observed locally by Dalton and Charnock. In Scotland

where the rainfall is much greater than in the south of England, and the general temperature and atmospheric influences less favourable for the promotion of evaporation, the latter has been found by the Engineer of the Paisley Waterworks and others to be less than in the southern counties of Great Britain.

In the following table I have placed in juxta position the results arrived at by different observers.

| Authority. | Locality. | Mean annual rainfall. | Evaporation from surface or difference between rainfall and available supply. | Remarks on nature of surface to which the observations refer. |
|---|---|---|---|---|
| Charnock | Ferrybridge | 24·6 | 19·72 | Porous well drained soil |
| Dalton | Manchester | 33·56 | 25·15 | Ordinary mould with vegetation on surface. |
| Howard | ... | 36· | 30·47 | General surface of Gt. Britain. |
| Thom | Paisley | 54· | 18· | Small gathering grnd possessing well drained surface, watered by numerous catch-water drains. |
| Beardmore | Bute | 45·4 | 22·5 | Low country. |
| Ditto | Rivington Pike | 55·5 | 31·3 | Elevated district, 1545 ft. above sea. |
| Dickenson | | 26·6 | 15·64 | Ordinary porous soil. |
| Charnock | Ferrybridge | ... | 32·60 | Moist undrained soil. |
| Ditto | Ditto | ... | 35·03 | Water surface. |
| Dalton | Manchester | ... | 44·43 | Water surface. |

The inferences to be derived from an inspection of this table are,—first, that the values assigned to evaporation from land surfaces by these different authorities are, (with the exception of that given by Dickenson), quite compatible with each other if due allowance be made for the variations of the temperature, geological configuration, soil, and rainfall of the places of observation: and, secondly,—that when the annual rainfall exceeds the annual average quantity, *the annual proportionate amount thereof evaporated does not also increase as a necessary consequence of such augmented rainfall.* I may here remark that Charnock's observations indicated at the least annual evaporation during the five years over which his observations extended, had occurred during a year when the annual rainfall had been about the average of the five years. This shows the futility of assuming (as too frequently has

been done), *a certain proportion to exist between the rainfall and the available supply.*

Mr. Dickenson's Tabulated Quantities, which indicated an annual amount of evaporation so greatly differing from the results of all other authorities, were, I believe, made for Mr. Parkes, the well known agricultural surveyor, and were inserted without acknowledgement of their author's name, in Dempsey's Treatise on Drainage. But in Table VI. the very great error was committed of obtaining the *mean-annual evaporation* for the total rainfall of the year by adding up the mean monthly evaporations and dividing the sum by twelve; which result would only be correct if the rainfalls for each month were precisely equal.* Hence the annual evaporation adopted, on Dempsey's authority, by your Committee, was not only based on observations of an exceptionable nature, as just shown, but was also greatly vitiated by a gross mathematical absurdity, which, whether due to Dickenson or Dempsey, was very inexcusable in a professedly scientific series of Tables.

The inadequate rate of evaporation from the ground, as thus assumed by your Committee, is still further shown by its actual application.

Thus, if thirty-six inches represent the rainfall at the Upper Plenty, the evaporation, according to the Committees assumed rate, 0.58, would be only 20.88 inches;—that is, a quantity *less* than has been observed on the average of gathering grounds, whose discharges have been guaged in Scotland, and *very much less* than has been found to prevail in the South of England. Yet how obviously must the evaporation from the surface of the ground be greater here, even on the most favorable surfaces for lessening evaporation, when the high temperature, hot winds, and clear dry atmosphere of this colony are considered!

Although I cannot admit that the configuration of the surfaces of the Upper Plenty District is so unusually peculiar as to warrant the excessively low rate of evaporation assumed by your Committee, yet a portion of these surfaces

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* Let $R_1, R_2, R_3, R_4$, &c., denote the respective amounts of rainfall in inches for each successive month; $E_1, E_2, E_3, E_4$, &c., the rates of evaporation corresponding to each successive month; then true mean annual rate of evaporation $= \frac{E_1 R_1 + E_2 R_2 + E_3 R_3 + E_4 R_4 + \&c.;}{R_1 + R_2 + R_3 + R_4 + \&c.;}$ but according to Dempsey it would be most erroneously represented by the expression $\frac{E_1 + E_2 + E_3 + E_4 + \&c.}{12}$

is so far favorable for lessening evaporation, as to render, in my humble opinion, Dr. Wilkie's estimated rate of evaporation too great.

For the steep slopes of the ordinary forest ranges comprised within the watershed of the Plenty above Yan Yean, promote the rapid conduction of rain-water to the channels of drainage, and therefore tend to diminish evaporation; this obvious diminution is, however, to a considerable extent, counterbalanced by the increased evaporation that occurs on some extensive tracts of wet undrained land, from whose surface the evaporation is, according to Charnock, nearly as great as from a sheet of water. In this condition are the swamps that extend from the base of Mount Disappointment to the village of Whittlesea,—a swampy tract north of Sherwin's range, the sides of several of the mountain ravines, and even part of the table land on the main range.

From the want of extended meteorological observations taken in connexion with the Upper Plenty districts, or what would have been much more satisfactory, a complete series of stream-guagings to determine the annual discharge, the available rainfall of the district can be only analogically eliminated from the general data afforded by the most trustworthy English observations on evaporation, corrected for the average differences of temperature for the various months of the year, in London and Melbourne, as given in the *Statistical Register* for Victoria. Moreover, as wind, and the hygrometrical state of the atmosphere exercise a marked influence on evaporation, independently of temperature; and as their action is more intense here than in England, some additional corrections should be applied to the English data for this increased action. Due consideration must also be given to the favourable nature of part of the surface of the Upper Plenty district, especially that portion draining direct into the reservoir. Having made allowance for all these contingencies I have arrived at the conclusion that the total annual rainfall at the Upper Plenty may be taken as equivalent to thirty-six inches, and that the amount thereof evaporated may be assumed to be 30·8 inches, leaving the amount available for supply 5·2 inches, over 44,000 acres. But if cuts were made on the catch water principle the amount available might be greatly augmented.

The annual evaporation from the surface of water in England amounts to from thirty-four to forty-four inches. Both Dr. Wilkie and Messrs. Acheson and Christie, have assumed nine feet as the annual loss from evaporation on the

surface of the reservoir at Yan Yean; whilst Mr. Blackburn considered three feet would be the maximum loss, and others have coincided with his opinion, citing instances of the small decrease in depth observable in certain ponds.

Reference to the observed decrease in depth during a specified period in a pond, is of no use in facilitating the inquiry into the amount of evaporation from the surface of the reservoir, unless the rainfall during that period, the area of the pond, and the area of the ground draining into the pond, be given.

In the following case these were attainable :—In the vicinity of my residence near the Yarra is a pond, to whose surface I occasionally have recourse for testing the adjustment of my spirit levels. The area of this pond is about one and a-half acres, its greatest depth ten feet, and the area of the ground draining into it about nine acres.

The surface of the area of drainage is either trap rock, or a thin coat of soil derived from its disintegration, and resting on a substratum of very stiff impervious clay. The height of the surface of the pond above the nearest point of the Yarra was ascertained by me to be, on March 1st, 1855, fifty-one inches. On December 1st, 1854, one of my men defined, by a peg driven down flush with the surface of the pond, its level on that day, and on March 1st I found the water had sunk 16·2 inches. The proportion of the rainfall draining into the pond, from the small area comprised by its watershed, was assumed to be, for the three months of December, January, and February, 0·15 of the small amount of rain that fell on that area during that period. The rainfall during the three months was known by reference to the rain guage kept in Melbourne. From these data I computed the evaporation for those three months to be 24·6 inches.

Having been aware that evaporation from water in small vessels, constructed of materials that are good conductors of heat, proceeds with very much greater rapidity than in large vessels or ponds, I should not feel safe in placing any reliance on the results afforded by the small copper vessels employed by Dr. Davey, and which have led Dr. Wilkie and your Committee to assume nine feet as the annual amount of evaporation from the surface of the Yan Yean reservoir.

During the month of February I placed in an exposed site in my garden a large butt, which I filled nearly to the brim with water, and protected the external wood-work of the butt from the influence of the sun and hot winds by woollen rugs. Having unfortunately lost the record of my observa-

tions on the water in this butt, I can only state generally that the decrease in depth in consequence of evaporation was remarkably less than according to Dr. Davey's observations; and that during the prevalence of one hot wind the observed decrease in twenty-four hours was only half an inch.

I must, however, protest against the greatly exaggerated notions relative to the diminished rate of evaporation in large reservoirs entertained by some practical men. For instance, Mr. Stirrat, the promoter of the gravitation schemes of water supply in Scotland, actually stated in evidence, that in large reservoirs the evaporation was counterbalanced by dew condensed on the surface of the water—a remark, which, if true, would have entirely precluded the possibility of carrying on the well-known process of obtaining salt by evaporation of sea water in large tanks formed near the sea coasts.

If, in the absence of a complete and satisfactory series of observations on the evaporation during the summer months here, from water contained in a vessel of adequate depth and capacity, well protected from the influences of external temperature, my experiment, made during December, January, and February, on the pond, be considered to afford some criterion of the probable influence of hot winds upon the Yan Yean reservoir, then the approximate deterioration of the evaporation of the other months of the year can be arrived at with tolerable precision. For if we omit December, January, and February, the mean temperature of all the other months in the year in this colony agree very nearly with the mean temperature of some of the months in England, for which the rates of evaporation from water surfaces have been registered. By basing a calculation on this principle, and applying some additional correction for the frequent occurrence of dry winds here, &c., I have computed the probable evaporation from the surface of the reservoir to be as follows:*—

| | INCHES. |
|---|---|
| Evaporation for December, January and February, as determined from my experiments on the pond. | 24·6 |
| Evaporation for March, April, and November, (determined by analogical deduction, from a comparison of English and Australian Meteorological observations, &c. ... ... ... | 19· |
| Evaporation for March, September, and May. ... | 14·2 |
| Evaporation for June, July, and August. ... | 8·3 |
| | 66·6 |

* During the period that has elapsed since the lecture of this paper and my inspection of the proof sheets, the President of the Commission of Sewerage

In investigating the probable supply of water derivable from the mountains, the possibility of any of the copious streams in the ravines of Mount Disappointment being derived from sources beyond the apparent limits of the water-shed of the Plenty must next be considered.

When I guaged these streams and examined their sources in 1852, the fine body of water that I saw gushing out with great velocity from a fissure in the granite, and forming the source of the Saw Pit Creek, on the western branch of the Plenty, led me to investigate this point; as I was aware, that in the island of Hong Kong, copious streams gush out of similar fissures in the granite formation there, and discharge a much greater quantity of water than the total rainfall of the island.

But on examining the sources of the eastern branch of the Plenty, I saw that the high table land forming the dividing range between the Plenty and the tributaries of the Goul-

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and Water Supply has published a vindication of the Yan Yean Scheme of Water Supply. In the course of his observations, he states that I have committed a palpable error, in ignoring, in the above analogical deduction, the difference in the length of days here and in England, for the months of corresponding mean temperature; as he is of opinion that the evaporation, on account of longer duration of daylight, is greater in England, during a month of a certain mean temperature, than would be found to occur here, during a month possessing the same mean temperature. But Mr. Griffiths, in the calculation by which he illustrates his views on this subject, unfortunately falls into the error of supposing that *evaporation invariably ceases at nightfall.* I, therefore, beg to remark, that in this Colony, where dry windy nights are of such frequent occurrence, the nocturnal evaporation is often very great; so much so, in fact, as to render the correction, to which Mr. Griffiths attaches so much importance, of a very trivial and indefinite nature; not, however, ignored by me, as he supposes, but found to be more than counterbalanced by the greater dryness of the atmosphere in this Colony. Mr. Griffiths further states, that I am one who would prefer the Yarra, with "its tanneries, fellmongeries, and the thousand other daily increasing sources of pollution," to the Plenty. The *nearest point* to Melbourne, at which I ever proposed to derive any supply, was two miles higher up the river than the point where the analytical chemist of the Commission found the Yarra water to be *purer* than the Plenty water; and as regards the nuisances on the banks of the Lower Yarra, below Dight's Mills, I recollect having once stated the necessity, in my humble opinion, (in a casual conversation with Mr. Griffiths, two years ago,) of some legislative enactment to check the contamination of the water.

I have also lately received from T. E. Rawlinson, Esq., Engineer to the Fitzroy Ward Improvements, a letter kindly conveying to me the result of his observations on the Plenty. Mr. Rawlinson's high professional standing and long connexion with Yan Yean impart great weight to his opinions on the Water Supply. He considers that the minimum flow of the eastern arm of the Plenty is 4000 gallons per minute, and is convinced, from long personal observation of the Yan Yean Swamp, that the evaporation from the surface of the reservoir will be very much less than has been estimated by some of the members of this Society.

burn, was sufficiently extensive to maintain the permanent discharge of the streams in question in the following manner: the rain percolates through the very permeable soil on the top of the range, and lodges in extensive interior cavities and fissures in the granite; and from these subterranean reservoirs the water is gradually exuded at lower levels, through the spongy masses of decomposed vegetation which fill up the external interstices of the granite, and constitute the soil from which spring up, in such rank luxuriance, the gigantic mountain Eucalyptus, and dense undergrowth of tree-ferns and creepers that choke up the ravines of Mount Disappointment.

This opinion of the probable cause of the very permanent and regular flow during the summer months of the mountain streams, was briefly enunciated in one of my reports in 1852, and has been since corroborated by Messrs. Acheson and Christie.

During the four hottest months of the year, the enormous quantity of water lost from the effects of evaporation and absorption in the river swamps between Mount Disappointment and Whittlesea (equivalent to a discharge per minute of about 2500 gallons) would render it necessary that, for these months, a quantity of water, equivalent to a discharge of at least 3000 gallons per minute, should be deducted from the total yield of the mountain streams, in order to maintain a sufficiency of water in the Lower Plenty for the adequate supply of the setttlers and stock thereon. During the other eight months of the year, a quantity equivalent to a discharge of 2000 gallons per minute would suffice to effect this.

The guagings of the Plenty made from time to time by Mr. Blackburn, Mr. Jackson, your Committee, and myself, are from their want of connexion in a regular series, of little value in affording data for determining the total annual discharge of the Plenty. The information afforded by the settlers on that river relative to its winter discharge, floods, &c., is also exceedingly contradictory, I therefore considered it safer, as explained in some of my foregoing remarks, to endeavour to arrive at some estimate of the supply on general principles.

I submit with much diffidence the following very rough approximation to the probable amount of population that the Yan Yean scheme would prove adequate to furnish with a sufficient supply of water. Since my lecture of this paper I have however arrived at the conclusion, that sufficient experiments on dew have not been made in this colony to

enable its influence on the augmentation of the water supply to be definitively determined; and as I would wish to give a *safe estimate*, at any rate, (or less rather than more, than the probable supply), I have now excluded any separate allowance for dew from the calculation.*

*Supply.*

| | GALLONS. |
|---|---|
| Available rainfall, assumed to be equivalent, as already explained, to 5·2 inches, over total surface 44,000 acres, whose drainage either flows into the Plenty above the cut, or else flows direct into the reservoir. ... | 5,175,950,208 |
| Rainfall on surface of reservoir,—36 inches on 1,300 acres ... ... ... ... | 1,058,377,320 |
| | 6,234,327,528 |

*Demand.*

| | |
|---|---|
| Quantity required to maintain an adequate flow in the Lower Plenty ... ... ... | 1,227,240,000 |
| Evaporation,—66·6 inches from 1,300 acres of water surface ... ... ... ... | 1,958,626,613 |
| Contingent allowance for loss of flood-water, during excessive rains, absorption, &c., 6 inches over 1,300 acres ... ... ... | 176,452,848 |
| Balance, equivalent to the supply, at the rate of twenty-five gallons per head, per day, of a population 313,880 persons, or a population of about 196,000 if the larger rate of forty gallons per head, per day, be assumed ... | 2,872,008,067 |
| | 6,234,327,528 |

* Dr. Hales, in his Vegetable Statistics, states, from experiment, that "the moister the earth is the more dew falls upon it in the night; and more than double the quantity of dew falls upon a surface of water than there does on an equal surface of moist earth." The author of the recent Report to the Board of Health, on the supply of water derivable from the Farnham Tertiary formation, holds the same opinion. Professor Young, in article Dew, in Rural Encyclopædia, states that a water surface condenses more dew than any other surface. White considered that the permanent character of the ponds occasionally met with on the crest of the South Downs was to be attributed to the large amount of dew condensed on the surface of such ponds. The assertion of Mr. Stirrat, in reference to the influence of dew on the large reservoirs on his bleaching grounds, has already been alluded to. It has been supposed by some writers, that water has a capacity to assimilate to itself the vapour in the atmosphere, under certain conditions, even though the temperature of the surface of the water should exceed that of the air above it. Unless this capacity existed, the surface of water (if its relative temperature to that of the air be only considered) could seldom effect the condensation of dew. In Great Britain every one must have noticed, on nights otherwise clear and serene, long serpen-

I have arrived, therefore, at the conclusion, that in ordinary years no fear need be entertained, but that a very abundant supply of water will be derivable from Yan Yean, for a population three times greater than the present population of Melbourne. But that, whenever this colony is again afflicted with such another drought as that of 1838 and 1839, a failure in the supply would occur.

The great area of the reservoir will cause the water to be occasionally so violently agitated by wind as to obviate some of the evils that arise from the storage of water. I do not, therefore, anticipate that the Plenty water will undergo much deterioration in the reservoir, unless during the prevalence of an extraordinary drought.

It has been suggested, that if an additional supply of water be required, it could be conveyed into the reservoir either from the King Parrot Creek, on the other side of the main dividing range, or from the Diamond Creek.

I believe the able engineer of the Water Commission could not have examined these streams closely. For I have inspected the source of the King Parrot Creek, and being also acquainted with the country within the watershed of the Diamond Creek, I am induced, from my local knowledge, to form a very unfavourable opinion of this mode of increasing the supply.

In the case of the King Parrot Creek, a drift-way of considerable length would have to be made, at a great depth below the surface, through hard, igneous or plutonic rock, and the difficulties attending the execution of such an excessively costly work, would probably be augmented by the influx of water during its progress. With regard to the Diamond Creek, several of its tributaries, and steep intervening schistoze ranges, would have to be crossed, before the waters of the main creek could be conveyed to the Yan Yean Reservoir. In point of fact, the western tributary of the

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tine bands of mist defining the courses of rivers or large sheets of water; and in Australia I have occasionally, on clear nights, seen similar mists suspended over lagoons, and which mists saturated my hair with moisture on traversing them. Mists of this very circumscribed nature are much less frequent in Australia than in Europe; yet, if they resulted, as some have supposed, from the temperature of the air being below that of the surface of the water, such mists ought to be of more frequent occurrence here, where the temperature of the atmosphere during night is so remarkably less than during day, and consequently the temperature of water surfaces during night generally greater than that of the air. I venture to hope that the phenomena connected with vapour in the atmosphere here will be elucidated by Mr. R. Brough Smyth, whose accurate and judiciously conducted observations will ultimately render his name our chief authority on the Meteorology of this Colony.

Diamond Creek, called the Sugar Loaf Creek, would be the only stream that would be practically available as a feeder for the reservoir; and although the watershed area of the Sugar Loaf Creek is very limited, and its discharge in summer very insignificant, much tunnelling through hard schists would be requisite, in order to convey any portion of its water to Yan Yean.

The contamination of river water caused by a dense population on its banks, has been very frequently assigned as a very cogent reason for preferring the Plenty water to the Yarra water.

Yet, for that very reason, a decided preference should have been given to the Yarra. For the banks of the Upper Yarra consist, with few exceptions, of steep, rocky, stringy-bark ranges, frequently precluding all access to the water, and totally unsuited for the location of a dense population. But the Upper Plenty District, around the Yan Yean reservoir, is a fine, rich, well-watered, and well timbered tract of country, already possessing within its limits, a numerous agricultural population, and the rising village of Whittlesea.

Now, supposing that one of the owners of land abutting on the Yan Yean reservoir, or draining into it, were to convert such land into a township, and by puffing it into notoriety on account of its proximity to a magnificent fresh-water lake, lovely scenery, rich land, and so forth, were to cause the township on paper to become a township in reality, a population of only two thousand persons thus located, would cause a greater amount of deterioration in the water of the reservoir, than would be inflicted on the Yarra by a densely-peopled town of fifty thousand inhabitants formed on the banks of that river at Heidelberg. Although the Plenty affords an unusually soft and excellent water, that of the Yarra, taken from any point above Dight's Mills, has been proved by a quantitative and qualitative analysis to be yet more excellent; and I see no reason for departing from the opinion I formerly expressed, relative to the superior purity of a supply derivable from the Yarra, above the Yarra Bend Asylum. Those persons whose impressions of the Yarra have been influenced by its sluggish aspect near Melbourne, would have formed a more favourable opinion of this beautiful stream had they seen it in the upper portions of its course, where it rapidly rushes down its stony bed with sparkling brilliancy, or else forms foaming cataracts over ledges of rock.

In concluding my remarks, I have avoided all allusions to


NATURAL HISTORY.